EFFECT OF S GLASS FIBRE REINFORCEMENT ON THE FLEXURAL PROPERTIES OF COMPOSITES – AN IN VITRO STUDY

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MASTER OF DENTAL SURGERY

BRANCH – I

PROSTHODONTICS AND CROWN & BRIDGE

MAY - 2018

CERTIFICATE - I

This is to certify that the dissertation titled "**EFFECT OF S GLASS FIBRE REINFORCEMENT ON THE FLEXURAL PROPERTIES OF COMPOSITES – AN IN VITRO STUDY**" is a bonafide work done by **Dr. M.KANMANI**, Postgraduate student, during the course of the study for the degree of "Master of Dental Surgery" in Department of, **PROSTHODONTICS AND CROWN & BRIDGE**, KSR Institute of Dental Science and Research, Tiruchengode during the period of 2015-2018, under our supervision and guidance.

Dr. C.A.MATHEW, MDS

Guide, Professor and Head,

Dept. of Prosthodontics and
Crown & Bridge,

KSR Institute of Dental Science and
Research,

Tiruchengode – 637215.

Dr. G.S.KUMAR, MDS

Principal,

KSR Institute of Dental &
Science and Research,

Tiruchengode – 637215.

DECLARATION BY THE CANDIDATE

TITLE OF DISSERTATION	EFFECT OF S GLASS FIBRE REINFORCEMENT ON THE FLEXURAL PROPERTIES OF COMPOSITES – AN IN VITRO STUDY
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NAME OF THE GUIDE	Dr. C.A.MATHEW M.D.S
HEAD OF THE DEPARTMENT	Dr. C.A.MATHEW M.D.S

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KSR INSTITUTE OF DENTAL SCIENCE & RESEARCH
KSR Kalvi Nagar, Tiruchengode-637 215, Tamilnadu.
Phone : 04288-274981, Fax : 04288-274761,
email : ksrdentalcollege@yahoo.com

Chairman
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Prof. & Head Dept. of Biotechnology
KSR College of Technology,
KSR Kalvi Nagar, Tiruchengode.

Member Secretary
Dr. G.S. KUMAR, MDS.,
Principal,
KSR Institute of Dental Science & Research,
KSR Kalvi Nagar, Tiruchengode.

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To

Dr.M.Kanmani,
Postgraduate Student,
Dept. of Prosthodontics,
KSR Institute of Dental Science & Research,

*****

Your dissertational study titled "EFFECT OF S-GLASS FIBRE REINFORCEMENT ON THE FLEXURAL PROPERTIES OF COMPOSITES – AN IN VITRO STUDY" presented before the ethical committee on 15th Dec. 2015 has been discussed by the committee members and has been approved.

You are requested to adhere to the ICMR guidelines on Biomedical Research and follow good clinical practice. You are requested to inform the progress of work from time to time and submit a final report on the completion of study.

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CERTIFICATE - II

This is to certify that this dissertation work titled "**Effect of S Glass Fibre Reinforcement on the Flexural Properties of Composites – An In Vitro Study**" of the candidate **Dr. M.Kanmani** with registration Number **241511251** for the award of **Master of Dental Surgery** in the branch of **Prosthodontics and Crown & Bridge**. I personally verified the urkund.com website for the purpose of plagiarism Check. I found that the uploaded thesis file contains from introduction to conclusion pages and result shows **2** percentage of plagiarism in the dissertation.

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LIST OF ABBREVATIONS

FRC	Fibre Reinforced Composites
FPD	Fixed Partial Denture
SiO_2	Silicon dioxide
MgO	Magnesium oxide
CaO	Calcium oxide
RCT	Randomized Control Trial
ANOVA	Analysis of Variance
HSD	Honest significant difference
Std	Standard
df	Degree of freedom
mm	millimetre
mg	milligram
µm	micrometre
Vol.	Volume
Wt.	Weight
MPa	Mega Pascal
GPa	Giga Pascal
Bis GMA	Bisphenol A- glycidyl methacrylate
TEDGMA	Triethylene glycol dimethacrylate
UDMA	Urethane Dimethacrylate
PMMA	Poly Methyl Methacrylate
HEMA	Hydroxy ethyl methacrylate
MDP	Methacryloyloxydecyl Dihydrogen Phosphate

TERMINOLOGIES

1. **Fixed partial denture**

Any dental prosthesis that is luted, screwed, or mechanically attached or otherwise securely retained to natural teeth, tooth roots, and/or dental implants/abutments that furnish the primary support for the dental prosthesis and restoring teeth in a partially edentulous arch; it cannot be removed by the patient.

2. **Fiber-reinforced composite resin**

Composite resin impregnated with glass, carbon, or polyethylene fiber; fibers may be composite resin impregnated by the provider or pre-impregnated by the manufacturer; dental application includes resin-bonded prostheses and posts.

3. **Provisional restoration**

A fixed or removable dental prosthesis, or maxillofacial prosthesis designed to enhance esthetics, stabilization, and/or function for a limited period of time, after which it is to be replaced by a definitive dental or maxillofacial prosthesis; often such prostheses are used to assist in determination of the therapeutic effectiveness of a specific treatment plan or the form and function of the planned definitive prosthesis

4. **Flexural strength**

Force per unit area at the point of fracture of a test specimen subjected to flexural loading

5. **Elastic modulus**

Relative stiffness of a material; ratio of elastic stress to elastic strain

INTRODUCTION

The increasing demands in esthetic dentistry along with the developments in manufacturing technology have led to the production of many dental materials with improved physical and mechanical properties for clinical applications.

In the recent years, the use of light cured composite resins has been rapidly increasing for both the anterior and posterior restorations because of the advent of nano composites. Nano composites, either nanohybrid or nanofilled are superior in strength than traditional hybrid composites and also have optimal polishability when compared to microfilled composites. Fillers in nanohybrid composite ranges from micron sized to nano sized particles. Fillers are added to the resin matrix as reinforcement to improve the physical and mechanical properties, to reduce polymerisation shrinkage, to reduce thermal contraction, to decrease water sorption, to impart radiopacity and to optimize the viscosity of the resin matrix [1, 2].

At present, glass fibres are the most commonly used and preferred reinforcing material for composites. Carbon/graphite, aramid, boron, metal fibres and polyethylene fibres are also used. Although carbon fibers are superior to glass and polyethylene fibers in increasing the mechanical properties of resin composites, they pose an esthetical disadvantage because of their black appearance [3]. Among the glass fibres, 'E' and 'S' glass fibres are commonly used. E stands for electrical grade and these fibres predominantly consist of SiO_2 and CaO and S stands for strength and the fibres are made of SiO_2 and MgO [4].

Glass fibres are classified into long-continuous and short-discontinuous; long fibres are again sub-grouped into unidirectional-long, bidirectional-woven and braided fibres. Pre-impregnated and non-impregnated fibres are also available. Mechanical properties of FRCs depend on some factors like fiber orientations, amount of fibres, adhesion of fibres to polymer matrix, impregnation of fiber with the matrix polymer, fiber type, fibre's aspect ratio and volume loading.

FRCs for dental applications has been discussed in the literature since the early 1960s.For the past three decades, many in vitro and in vivo studies have been conducted to determine various properties of FRCs and they have become a material of choice for clinical applications such as reinforcement of complete dentures and removable partial dentures, fabrication of fixed partial dentures, endodontic posts, periodontal splints and orthodontic retainer [5].

The use of FRCs in clinical dentistry may solve many of the problems associated with a metal alloy substructure such as corrosion, toxicity, complexity of fabrication, high cost and aesthetic limitation [6]. They are utilised more due to the enormous demands for conservation, esthetics and immediate restoration are increasing now a days. But still literature evidence in the form of RCTs are lacking to support FRC as a definitive restoration [7].

FRCs are also used for the fabrication of provisional restorations. Provisional restorations must satisfy the requirements of pulpal protection, positional stability, occlusal function, ability to be cleansed, margin accuracy, wear resistance, strength and esthetics [8]. The strength of provisional restorations is important, particularly when the patient must use the provisional restoration for an extended period to assess the prognosis, when the patient exhibits parafunctional habits, when long-span prosthesis is planned or in full mouth rehabilitation cases.

Flexural strength and modulus are important for both definitive and provisional restorations particularly in high stress bearing areas which are exposed to tension and compression forces. Thus the aim of the present study was to investigate the effect of short-S glass fiber reinforcement on the flexural properties of high strength nano hybrid composites.

STATEMENT OF PROBLEM

Glass fibre reinforced composites have already become an alternative to traditional definitive restorations and as effective long term provisional restorations. Many in vitro and in vivo studies have already been carried out to support the reinforcement of composite resins with long unidirectional fibres. Composite resin reinforcement with short glass fibres, their isotropic properties and their influence in improving flexural properties have not been studied effectively so as to come to a conclusion.

AIMS AND OBJECTIVES

AIMS

The aim of this study is to determine the flexural properties of composite resins reinforced with S-glass fibres.

OBJECTIVES

1. To evaluate and compare the flexural properties of composite resin(Polofil NHT, Voco -Nanohybrid composite resin) with and without the reinforcement of short S glass fibres (Endure fibres, Remuscence)
2. To evaluate and compare the flexural properties of composite resin reinforced with short S glass fibres with different volume proportions.

NULL HYPOTHESIS

1. There is no significant difference in the flexural properties of composite resins with and without the reinforcement of short S glass fibres.
2. There is no significant difference in the flexural properties of composite resins reinforced with short S glass fibres with different volume proportions.

REVIEW OF LITERATURE

- **Altieri JV, Burstone CJ, Goldberg AJ, Patel AP (1994)[9]**

This in vivo pilot study was conducted in 14 patients to evaluate the survival rates of fixed partial dentures for single tooth replacement fabricated using fibre reinforced composites. Two types of failures were observed from this study (i.e.) adhesive failure and cohesive separation. The longest survival rate among the given restorations was found to be 24 months when replacing a missing mandibular molar.

- **Behr M, Rosentritt M, Lang R, Handel G (2000)[10]**

This experimental study investigated the flexural properties of composites reinforced with two different systems (i.e.) manual adaptation (S-2 glass fibres) and vacuum/pressure adaptation (R glass fibres). Specimen testing was done after 24 hours in water, 30 days in water and after thermo cycling. The vacuum/pressure system had resulted in high fibre content than manual adaptation but significant difference between the two groups was not observed. So it was concluded that matrix composition and bond between matrix and fibres were major determinants than fibre content.

- **Vallittu PK, Sevelius C (2000)[11]**

This clinical study was conducted to evaluate the survival rate of fibre reinforced fixed partial dentures with a mean follow-up period of 14 months. The fibres were unidirectional E glass fibres. 31 laboratory fabricated prostheses were luted using resin cements which replaced the missing teeth in both the arches; both in the anterior and posterior regions. The retainers were given by means of inlays, surface retention, full coverage crowns and also by combinations. During the follow up period, 2 patients were reported with debonding of the prostheses with intact framework. So the authors concluded that the prostheses had functioned adequately during the follow-up period and gave recommendations for further long term clinical studies.

- **Ellakwa AE, Shortall AC, Shehata MK, Marquis PM (2001)[12]**

In this study, composite resins reinforced with unidirectional polyethylene fibres were assessed for flexural properties. The fibres were placed at two positions; at tensile side and away from tensile side. The fabricated specimens were either water stored or dry stored for 2 weeks. Both the dry and wet stored specimens of fibre reinforced groups showed higher flexural strength than unreinforced groups. Among the reinforced groups, the group with fibres placed on the tensile side showed late crack development and propagation.

- **Haselton DR, Diaz-Arnold AM, Vargas MA (2002)[13]**

This experimental in vitro study was carried out to compare the flexural strength of specimens fabricated using 5 methacrylate based resins and 8 bis-acryl resins. The prepared specimens were stored in artificial saliva for 10 days before performing the three point bending test. From the results obtained, Provipont, a bis-acryl resin was found to have the highest flexural strength (123.6 MPa) than the other tested materials. The strength obtained from Provipont was statistically significant to all methacrylate resins and some bis-acryl resins (Unifast LC, Instatemp, Temphase and Provitec) and insignificant than that of Integrity, Protemp 3 Garant and Luxatemp (bis-acryl resins)

- **Lassila LV, Nohrström T, Vallittu PK (2002)[14]**

This experimental in vitro study was carried out to analyse the flexural properties of fibre reinforced composites. The specimens were tested under three conditions- dry specimens, water stored specimens and reconditioned specimens after water storage. Flexural strength varied in relation to the duration of water storage and fibre-volume fraction. This article also discusses about the nature of the polymer matrix and types of adhesives in influencing the water sorption of the fibre reinforced composites.

- **Behr M, Rosentritt M, Handel G. (2003)[15]**

This experimental in vivo study was conducted to assess the survival rate of restorations fabricated using fibre reinforced composites. Crowns, Inlay FPDs and conventional FPDs were fabricated and cemented. After 3-years follow up, the survival rate of molars and inlay FPDs was 82% and 72% respectively. By assessing the failures (fracture, wear and discolouration), the authors concluded that the fibre reinforced composites should only be used for provisional restorations.

- **Hamza TA, Rosenstiel SF, Elhosary MM, Ibraheem RM (2004)[16]**

In this study, the authors compared the fracture toughness and flexural strength of 3 provisional restorative resins reinforced using glass fibres and polyethylene fibres. From the results obtained, the highest fracture toughness (2.74 MPa) was shown by PMMA resin + Fibrestick (unidirectional E glass fibres) combination and the highest flexural strength (199.6 MPa) by bis-acryl resin + Construct (silianized plasma treated polyethylene fibres). These values were statistically higher than unreinforced control groups.

- **Lassila LV, Vallittu PK (2004)[17]**

This experimental in vitro study was carried out to evaluate the flexural properties of composite reinforced with E glass fibres (unidirectional, continuous). Four different fibre positions were evaluated; horizontal – upper, middle, lower and vertical. The specimens were fabricated using 2 different light curing devices (i.e.) Liculite and Visio. From the results obtained, fibre reinforced groups with fibre position at horizontal lower and vertical side of the specimens were found to have higher strength than others. Comparing the 2 light curing devices, the highest mean flexural strength of 585 MPa and the highest mean flexural modulus of 16.6 GPa were obtained from the specimens polymerised using Liculite.

- **Jokstad A, Gokce M, Hjortsjo C (2005)[18]**

The authors conducted a systematic review to evaluate the scientific documentations of commercially available fibre reinforced polymers for the fabrication of fixed partial dentures (FPD). No randomized control trial was conducted for any available material; only one product (Vectris/ Targis) had literature in the form of 4 cohort studies. Case reports and case series were available for some materials and few materials did not have any clinical documentation. From the review, the authors concluded that using fibre reinforced polymers for the fabrication of FPD as experimental and not as a definitive restoration.

- **Nakamura T, Ohyama T, Waki T, Kinuta S, Wakabayashi K, Takano N, Yatani H. (2005)[19]**

This finite element analysis was conducted to analyse the position of the reinforcing material and the stress distribution within fixed partial denture models. From the analysis, it was concluded that the reinforcing materials could be placed at the bottom of the pontic than at the top to improve the strength and to decrease stress concentration.

- **Garoushi SK, Lassila LV, Vallittu PK (2006)[20]**

This experimental in-vitro study was conducted to evaluate the mechanical properties of composites (i.e.) flexural strength and compressive strength, reinforced with short E-glass fibres. This study was done in 2 parts to assess the volume fraction and length of fibres in improving the mechanical properties. By combining the results , it was concluded that the mechanical properties improved by adding 22 vol.% of fibres with 5mm length and that all the thermo cycled specimens showed deterioration in the values than the specimens under dry condition.

- **Piovesan EM, Demarco FF, Piva E (2006)[21]**

This in vivo study was conducted to find out the clinical outcome of polyethylene fibre reinforced fixed partial dentures. A total of 19 prostheses were fabricated and cemented to 13 patients; not more than 2 prostheses for the same patient. Composite resin, Acrylic resin teeth and natural tooth (same patient) were used for pontic fabrication. At the end of 3 and half years, 94.75% of complete survival was observed with 5.25% of survival with debonding.

- **Tezvergil A, Lassila LV, Vallittu PK (2006)[22]**

This experimental in vitro study was carried out to evaluate the polymerization shrinkage of composites reinforced with glass fibres, particulate fillers and no fillers. Fibres were reinforced with different orientation to the composite matrix (i.e.) unidirectional continuous, bidirectional continuous and randomly oriented short fibres. Fibre reinforced specimens showed less polymerization shrinkage than particulate filled and unfilled specimens. Among the fibre reinforced groups, unidirectional continuous fibres were found to have low shrinkage but the shrinkage mainly occurred transversally to the fibre direction.

- **Garoushi S, Vallittu PK, Lassila LV (2007)[23]**

This study was conducted to evaluate the mechanical properties of composites reinforced with short E-glass fibres (3mm length and 22.5 wt. %) and conventional composites. The specimens were dry stored or water stored before testing. It was concluded that the reinforced group showed improved mechanical properties than control group and dry stored specimens showed increased strength than the water stored specimens.

- **Garoushi S, Vallittu PK, Lassila LV (2007)[24]**

In this study, 3 experimental fibre reinforced resin specimens were compared to the unreinforced control group. The specimens were fabricated using zirconia model and a transparent matrix, depicting 2 retainers and a pontic. The fabricated specimens were evaluated for their load bearing capacity and examined for the type of fracture that occurred. All the reinforced groups showed improved load bearing capacity than the control group and the fracture observation in the control group specimens showed brittle type of fracture which was not repairable in comparison to the fracture of other group specimens.

- **Garoushi SK, Lassila LV, Vallittu PK (2009)[5]**

This review article has discussed about the clinical applications of fibre reinforced composites, along with their indications and contra indications. The use of unidirectional glass fibres in the fabrication of fixed partial dentures (both direct and indirect technique), for splinting periodontally weakened teeth and for orthodontic retention has been explained.

- **van Heumen CC, van Dijken JW, Tanner J, Pikaar R, Lassila LV, Creugers NH, Vallittu PK, Kreulen CM (2009)[25]**

This clinical trial was conducted to find out the survival rate of fixed partial dentures fabricated using fibre reinforced composite for replacing a single missing tooth in the anterior region. Two types of prostheses were included (i.e.) surface retained and hybrid retained (rests, grooves or conventional preparation). Out of 60 restorations given, 27 of them were in function at the end of 5-years follow up. It was concluded that 64% of survival rate was observed and no significance was observed between the two types of prostheses regarding failure.

- **Sideridou ID, Karabela MM, Vouvoudi EC (2011)[26]**

This experimental in vitro study was carried out to compare the properties between nanofilled and nanohybrid composites. The specimens were tested after immersing them in water or artificial saliva for 1 day or 30 days. From the results, nanohybrid (Grandio) showed highest flexural strength and modulus than others, after storing it for 30 days in either water or artificial saliva. There was no significant difference, observed between the water-stored or saliva-stored samples.

- **Garoushi S, Lassila LV, Vallittu PK (2012)[27]**

The authors have conducted a study to find out the effect of span length of flexural testing on properties of short fibre reinforced composites. Flexural test was conducted using different span lengths (20, 15, 10, 7, 6, 5mm) and values were obtained. From the results, the experimental fibre reinforced group with 5mm span length was found to have highest strength. The authors have also discussed about the changing nature of short fibres from isotropic to anisotropic in relation to that of span length (i.e.) decreasing the span length would alter the isotropic nature of short fibres to anisotropic.

Omid T, Venus MM, Farahnaz S, Asghar AA (2012)[28]

In this study, flexural strength of composite resin reinforced with glass fibres of different lengths was evaluated. The fibre length of 10, 15 and 20 mm lengths were tested and the specimen lengths were same as that of the fibre length. From the results obtained 10mm length specimens from control-unreinforced group and reinforced group showed high fracture load than other control groups and reinforced groups respectively. So the authors concluded that decreasing the span length would increase the load bearing capacity of the specimens.

- **Rosa RS, Balbinot CE, Blando E, Mota EG, Oshima HM, Hirakata L, Pires LA, Hübler R (2012)[29]**

This experimental in vitro study was conducted to compare the mechanical properties of 3 nanofilled composites. Appropriate tests were conducted for the different mechanical properties. From the results obtained, it was concluded that the weight of the filler content and their size played an important determining factor in improving composite properties. Among the tested composites, Filtek-350XT was found to have the highest flexural strength of about 123MPa.

- **Zhang M, Matinlinna JP (2012)[30]**

This review article discusses about the dental applications of E glass fibre reinforced composites. The author has analysed about the properties of composite matrix, different types of glass fibres particularly E glass fibres and its advantages and disadvantages and also explained about the factors to be considered when using fibre reinforced composites.

- **Garoushi S, Sailynoja E, Vallittu PK, Lassila L (2013)[31]**

This study was conducted to compare the physical and mechanical properties of 2 commercially available posterior composites, reinforced with short glass fibres (Alert and Xenius base) to 5 particulate filler composites. The effect of fibre length and their orientation in the resin matrix in influencing the mechanical properties was discussed. From the results, fibre reinforced composite groups were found to have improved properties than the other groups. Among the 2 fibre reinforced composites, Xenius base showed less polymerization shrinkage and increased flexural strength (124.3 MPa).

- **Rezvani MB, Atai M, Hamze F (2013)[32]**

This experimental in vitro study was conducted to evaluate the flexural properties of fibre reinforced composites. 3 different diameters (14, 19, 26µm) of E glass fibres were taken with same weight percentage and same length. Both the flexural strength and flexural modulus were increased by increasing the diameter of the fibre. But between the 19µm and 26µm diameter groups, no significant difference was observed. The authors had suggested using silane agents to improve the bonding between fibres and the matrix.

- **Duymus ZY, Karaalioglu FO, Suleyman F (2014)[33]**

This experimental in vitro study was carried out to compare the flexural strength of different materials used in the fabrication of provisional restorations. Materials were tested with and without fibre reinforcement. Both glass fibres and polyethylene fibres were used in this study for comparison. From the results obtained, visible light curing composite reinforced with polyethylene fibre was found to have the highest flexural strength (442 MPa) than other tested materials.

- **Gundogdu M, Kurklu D, Yanikoglu N, Kul E (2014)[34]**

This study was carried out to evaluate the flexural strength of two different composites (i.e.) nanofill and nanohybrid, reinforced with E-glass fibres and polyethylene fibres. Half of the specimens were stored in distilled water and other half specimens in mouthwash, in that, half specimens were tested after a day and the rest half in 7 days. Flexural strength was evaluated using universal testing machine by performing 3-point bending test. It was concluded that the type of fibre (glass) and composite (nanofill) were significant factors than storage solutions and storage time, in improving the flexural strength of composites.

- **Frese C, Schiller P, Staehle HJ, Wolff D (2014)[35]**

The authors conducted this follow-up study to evaluate the survival and functional rate fibre reinforced composite fixed dental prostheses. This study was conducted for a period of 4.5 years in 24 participants. The prostheses were either directly fabricated or semi-directly fabricated, which replaced the missing teeth in the anterior region. Out of the 24 given prostheses, 3 were considered as failures because they were severely damaged and lost. So to conclude, 21 prostheses had functioned adequately with the overall survival rate of 72.6% and functional rate of 85.6%, at the end of the study.

- **Shouha P, Swain M, Ellakwa A (2014)[36]**

This experimental in vitro study was conducted to evaluate the flexural properties of flowable dental composites reinforced using glass fibres (both E glass and S glass fibres) with different volume proportions and aspect ratios (AR). E glass fibres were tested for only low AR (5.2) and S glass fibres were tested for mid (68) and high AR (640). By analysing the results flowable composite in combination with 10 vol. % + 640 AR showed improved flexural strength (247.7MPa) than 20 vol. % + 68 AR (210.7MPa). So it was concluded that aspect ratio was more important to be considered than volume proportion for improving flexural properties of composites.

- **Khan AS, Azam MT, Khan M, Mian SA, Rehman IU (2015)[4]**

The authors have done a review of literature regarding glass fibre reinforced composites. Published articles from1964 to 2014 were included for this review. It has discussed about the different types of glass fibres, factors influencing the properties of glass fibre reinforced composites and summarized the results of earlier studies regarding mechanical properties and failures. From this review, it was concluded that glass fibre reinforced composites could be used as a substitute restorative material for traditional materials and adequate evidence was found in the literature to support that conclusion.

- **Maruo Y, Nishigawa G, Irie M, Yoshihara K, Minagi S (2015)[3]**

This experimental in vitro study was carried out to evaluate the flexural properties of composites reinforced with polyethylene, glass and carbon fibres. Within the limitations of the study, it was concluded that the flexural properties could be improved by addition of glass and carbon fibres than polyethylene fibres.

- **Naveen KS, Singh JP, Viswambaran M, Dhiman RK (2015)[37]**

This experimental in vitro study was carried out to evaluate the flexural strength of autopolymerising poly methyl methacrylate resin reinforced with silane treated and untreated E glass fibres. Both unidirectional and woven fibres were investigated. All the specimens were fabricated using a customized metal die and putty index, depicting two retainers and a pontic. From the results obtained, it was concluded that flexural strength could be improved by silane treated unidirectional fibre reinforcement. It was significantly higher than other groups such as control group, silane untreated unidirectional and woven reinforced groups.

- **Sonwane SR, Hambire UV (2015)[38]**

This in vitro study was conducted to compare the compressive and flexural strengths of five commercially available nanohybrid composites. The correlation between the filler content and its size in altering the mechanical properties was emphasized. Among the tested materials, Polofil NHT was found to have the highest flexural strength of about 171MPa and Charisma to have the highest compressive strength of about 176Mpa. Both the Polofil NHT and Charisma have the filler fraction of 83wt% and 80.5wt% and particle size of 0.004-3μ and 0.01-0.1μ respectively.

- **Vallittu. PK (2015)[39]**

This review article discusses about the aspect ratio of the filler and its influence in altering the properties of composite resin. It has also explained about the importance of critical length of fibres and the differences between short discontinuous and long continuous fibre reinforced composites in relation to anisotropic properties. Further studies are recommended by the author to correlate anisotropic properties with clinical applications.

- **Vidotti HA, Manso AP, Leung V, do Valle AL, Ko F, Carvalho RM (2015)[40]**

In this study, the composites reinforced with Polyacrylnitrile (PAN) nano-fibres were assessed for tensile properties, flexural properties and work of fracture (fracture toughness). The fibres were added with different weight proportion to the resin matrix. Both the tensile properties and work of fracture for the fibre reinforced groups were higher than the unreinforced groups and the flexural properties were not influenced by the presence of fibres

- **Bijelic-Donova J, Garoushi S, Lassila LV, Keulemans F, Vallittu PK (2016)[41]**

This study was carried out to compare the mechanical properties between particulate filler composite resin and short fibre composite resin. Appropriate tests were conducted for the investigated properties. Comparing the results, short fibre composite was found to have better mechanical properties than the other group, particularly fracture toughness was significantly improved. To conclude, fracture toughness was suggested to be considered as a reliable factor for assessing clinical performance of a material.

- **Bijelic-Donova J, Garoushi S, Vallittu PK, Lassila LV (2016)[42]**

This experimental in vitro study was conducted to compare the mechanical properties and structural characterisation of conventional composite resin and discontinuous-fibre reinforced composite resin. From the results obtained, fibre reinforced composite (i.e.) EverX Posterior was found to have the highest flexural strength and compressive strength of about 119MPa and 235MPa respectively for the dry specimens. Deterioration of properties after water storage was commonly seen for all the groups.

- **Bocalon AC, Mita D, Narumyia I, Shouha P, Xavier TA, Braga RR (2016)[43]**

This experimental in vitro study was conducted to evaluate the flexural strength, fracture toughness and polymerization shrinkage of S glass fibre reinforced composites. From the results, it was concluded that addition of short glass fibres to the composites has become a significant factor for increasing fracture toughness and to reduce polymerization shrinkage. There was no significant difference observed between the control group and reinforced groups in terms of flexural strength.

- **Bocalon AC, Mita D, Natale LC, Pfeifer CS, Braga RR (2016)[44]**

In this study, the composites reinforced with short S2 glass fibres were assessed for polymerisation stress, flexural strength, flexural modulus and maximum shrinkage rate. The glass fibres were cut into 1.5mm length and added to the experimental groups with the volume proportion of 3% and 6%. From the results obtained, it was concluded that adding the fibres to the composite resins would increase the polymerisation stress and decrease the flexural modulus of the specimens than the control group specimens.

- **Doozandeh M, Alavi AA, Karimizadeh Z (2016)[45]**

This experimental in vitro study was carried out to evaluate the flexural strength of fibre reinforced silorane based and methacrylate based composite resins. Among the fibre reinforced groups, 2 groups were fabricated with intermediate resin application. From the results obtained, methacrylate based composite resins were found to have higher flexural strength than silorane composite resins and addition of adhesive layer resulted in improved strength in both the groups.

- **Fonseca RB, de Almeida LN, Mendes GA, Kasuya AV, Favarao IN, de Paula MS. (2016)[46]**

In this study, 4 types of experimental composite specimens were tested. The specimens were fabricated with different fibre (E glass)/filler proportions. From the results obtained, specimens with 30 wt. % fibres and 47.5 wt. % fillers showed highest flexural strength and diametral tensile strength. SEM analysis of the specimen from the same group showed closer interaction of fibre/resin matrix without empty spaces than the other groups.

- **Shouha PS, Ellakwa AE (2016)[47]**

In this study, polymerisation shrinkage stress (PSS) of composite resins reinforced with short S2 glass fibres and E glass fibres were assessed. S2 glass fibres were cut and added in 3 different volume proportions; 5%, 10% and 20%. From the results obtained, it was concluded that the reinforcement with 5 Vol% of fibres had increased the PSS insignificantly than the unreinforced groups and 10 Vol% and 20 Vol% fibre groups showed significant increase in the PSS. The relation between the presence of fibres and depth of cure was also discussed by the authors.

- **Ahmed KE, Li KY, Murray CA (2017)[7]**

This systematic review was conducted to find out the longevity of fibre reinforced composite fixed partial dentures (FRC-FPD), by assessing the evidences, found in the already published literatures. Both prospective and retrospective studies were included, excluding in vitro studies and case reports. From this review, it was concluded that, FRC-FPD could be an alternative for single tooth replacement as a medium term treatment option but not for a long term treatment option and overall strength of clinical recommendation was considered as ‘moderate (B)’.

- **Garoushi S, Vallittu PK, Lassila L (2017)[48]**

This in vitro study was conducted to compare the mechanical properties and wear resistance of five commercially short fibre reinforced composites. The materials included in the study were Alert, Easy Core, Build It, TI Core and EverX Posterior. From the results obtained, it was evident that all the products had different properties; no product could be considered as superior in all the investigated properties. EverX Posterior had superior fracture toughness (2.4 MPa) and lowest wear values were observed for Easy Core and Build It as 19 and 22µm respectively.

- **Huang NC, Bottino MC, Levon JA, Chu TM (2017)[49]**

In this study, flexural properties of composites were assessed. The composites were reinforced with either strip or mesh fibres. Polymerisation was carried out in one stage or two stages. From the results obtained, the specimens reinforced with strip fibres were found to have improved flexural properties than mesh fibres and no significant difference was observed between one stage and two stage cured specimens.

- **Huang Q, Qin W, Garoushi S, He J, Lin Z, Liu F, Vallittu PK, Lassila LV (2017)[50]**

This experimental study was conducted to assess the physical and mechanical properties of short S-2 glass fibre reinforced resin composite. From the results obtained, experimental composite reinforced with S-2 glass fibres was found to have increased fracture toughness, flexural strength and hardness than unreinforced or other reinforced composites. On the contrary, experimental composite showed less flexural modulus than others, so the authors suggested further research to clarify the relation between flexural modulus and filler load.

- **Huang Q, Garoushi S, Lin Z, He J, Qin W, Liu F, Vallittu PK, Lassila LV (2017)[51]**

In this study, composites reinforced with S-2 glass fibres with 2 different lengths (1.5 and 3mm) were assessed for the flexural properties, double bond conversion and fibre length. Specimens fabricated with 3mm fibre length and 62.5 wt. % of particulate filler showed highest flexural strength and modulus. Double bond conversion was not influenced by the length of fibres that were used in this study.

- **Peterson RC (2017)[52]**

The author conducted a review to compare the particulate composite (PFC) resins and amalgam to fibre reinforced composite (FRC) resins. Both the PFC and FRC were inferior to amalgam in terms of modulus whereas other mechanical properties were superior. From this review, the author concluded that FRC resins with fibre length above critical length (i.e.) diameter to length ratio, could be used as a substitute to PFC and amalgam because of their improved mechanical properties.

- **Yanagida H, Tanoue N, Minesaki Y, Kamasaki Y, Fujiwara T, Minami H (2017)[53]**

This experimental in vitro study evaluated the flexural and shear bond strength of fibre reinforced composite resins. The specimens were fabricated using different polymerisation methods (i.e.) by using halogen light unit and metal halide light unit with different exposure time. From the results obtained, it was concluded that no significant difference was observed between different polymerisation methods in improving the mechanical properties but considering the fracture pattern of the specimens after testing, the authors had recommended to use high intensity light preliminary irradiation followed by secondary heating to get the desired results.

- **Wolff D, Wohlrab T, Saure D, Krisam J, Frese C (2018)[54]**

This 4- year prospective study was conducted to evaluate fibre reinforced composite fixed dental prosthesis in terms of survival, quality and surrounding periodontal tissue health. At the end of 4 years, the functional and overall survival rate of prosthesis was 73.5% and 53% respectively with acceptable periodontal health. Regarding quality, significant wear of the prosthesis, debonding and chipping of the veneered composite were present. .

MATERIALS

Table 1: Composition of the materials used in the present study

S.No	Materials	Company Name	Composition
1	Polofil NHT - Nanohybrid composite ; Shade A2 (Fig. No: 1)	VOCO	Matrix- Bis GMA, TEDGMA, UDMA, Fillers- Nano scaled particles with glass ceramic fillers- 83Wt%/68 Vol%
2	Single Bond Universal Adhesive (Fig. No: 1)	3m ESPE	MDP Phosphate Monomer, Dimethacrylate resins, HEMA, Vitrebond™ Copolymer, Filler, Ethanol, Water, Initiators, and Silane.
3	Endure - S glass fibres (Fig. No: 1)	REMUSCENCE	64%SiO_2 24%Al2O3 10%MgO

ARMAMENTARIUM

1. Stainless steel split mould with acrylic orientation jigs (Fig. No:2)
2. Glass slides (Fig. No:2)
3. Plastic instrument (Fig. No:2)
4. Cement spatula (Fig. No:2)
5. BP Handle and blades (Fig. No:2)
6. Sand paper – 400 grit (Fig. No:3)
7. Separating sheets (Fig. No:4)

8. Tissue papers (Fig. No:5)
9. Ruler (Fig. No:6)
10. Glass slab (Fig. No:7)

EQUIPMENTS

11. Incubator (Fig. No:8)
12. Digital balance (Fig. No:9)
13. Light cure unit (Fig. No: 10)
14. Universal testing machine - ZWICK ROELL (Fig. No: 11)
15. Scanning electron microscope – ZEISS (Fig. No: 12)

METHODOLOGY

GROUP A - 10 Specimens

Control group – Nano hybrid (NH) Composite

GROUP B - 10 Specimens

NH Composite + 2.5 Vol. % of S glass fibre

GROUP C - 10 Specimens

NH Composite + 5 Vol. % of S glass fibre

GROUP D - 10 Specimens

NH Composite + 7.5 Vol. % of S glass fibre

GROUP E - 10 Specimens

NH Composite + 10 Vol. % of S glass fibre

For the present study, a stainless steel mould of dimension 2*2*25mm was used for the fabrication of all specimens and an acrylic jig was fabricated using auto polymerising resin for orienting the split moulds. The shade of the composite resin used was A2.

Fabrication of specimen for control group (GROUP A)

The split mould along with the acrylic orientation jigs were placed on a glass slide with separating sheet in between them (**Fig. No: 13).** Composite resin (**Polofil NHT - VOCO**) was then placed and condensed into the mould and over that another separating sheet was placed (**Fig. No: 14 and 15**). A second glass slide was compressed over the separating sheet to confine the resin material within the mould **(Fig. No: 16)**. Each specimen was divided into 4 quadrants and each quadrant was cured for 20s as per the manufacturer's instructions to ensure adequate polymerization with a light curing unit (**Ivoclar Vivadent – LEDition of light intensity 600 mW/cm^2**) (**Fig. No: 17**). After completing the curing procedure for one side, the mould was turned over and the same steps were followed for the other side. Then the orientation jigs were disassembled from the mould set-up and the specimens were retrieved from the split mould **(Fig. No: 18)**. After retrieving, each specimen was examined for the presence of external voids. The specimens with voids were excluded from further testing.

FABRICATION OF SPECIMENS FOR FIBRE REINFORCED GROUPS

Determination of length of glass fibres

(Diameter of the fibre – 0.08mm (as given by the manufacturer))

The critical length of the fibre should be at least 50 times equal or greater than the diameter of the fibre. So the length of the fibre was calculated as 4 mm and maintained as constant for all the fibre reinforced groups (Groups **– B, C, D and E**). The fibres were cut manually with a fine surgical blade (**Fig. No: 19 and 20**)

Estimation of volume proportion and weight of the fibres for reinforcement

(Density of the fibre – 2.5 mg/mm^3; as given by the manufacturer**)**

Fibres were added with 4 different volume percentages (i.e. 2.5 Vol. %, 5 Vol. %, 7.5Vol. % and 10 Vol. %) to the total mould volume. Using the formula Mass = Density*volume, their weight was calculated as 6.25 Mgs, 12.5 Mgs, 18.75 Mgs and 25 Mgs respectively and weighed using a digital balance.

Assessment of weight of composite resin

The amount of composite resin needed for the fabrication of specimen for control group was determined as 372 milligrams (mgs). The total volume of the mould was 100 mm^3 (2*2*25mm). So 100 Vol. % = 100 mm^3 which was occupied by 372 Mgs of composite. The weight of composite resin was calculated for groups B, C, D and E as 362 Mgs, 353 Mgs, 344 Mgs and 334 Mgs respectively with respect to their volume percentages.

TABLE – 2: **Weight and Volume proportion of glass fibres and composite resin used for the fabrication of specimens for control group and reinforced groups**

GROUP	COMPOSITE (Wt. /Vol. %)	FIBRE (Wt. /Vol. %)
A	372 mgs/ 100 Vol. %	-
B	362 mgs/ 97.5 Vol.%	6.25 mgs / 2.5 Vol.%
C	353 mgs/ 95 Vol.%	12.5 mgs / 5 Vol. %
D	344 mgs/ 92.5 Vol.%	18.75 mgs / 7.5 Vol.%
E	334 mgs/ 90 Vol. %	25 mgs / 10 Vol.%

Fabrication of specimens

The Endure S glass fibres were already treated with Hydrofluoric acid by the manufacturer. Because of the dry nature of the fibres, they were further wetted by silane coupling agent (**Single bond universal adhesive – 3m ESPE**) to facilitate easy incorporation as well as to improve the adhesion between composite resin and fibres. After wetting, excess coupling agent was absorbed using tissue paper and fibres were added into the already weighed composite resin and thoroughly mixed using a cement spatula until a homogenous mix was obtained (**Fig. No: 21, 22, 23**). This was followed by the packing and condensation of the material into the mould. Polymerisation procedures were the same as that of the control group.

The fabricated specimens were placed in distilled water (**Fig. No**: **29)** and maintained at 37^0C for 24 hours in an incubator before testing. After 24 hours, all the specimens were taken from distilled water and finishing of the specimens was done using 400 grit sand papers. The dimension of each specimen was measured at three places; middle and at two extremities using a ruler.

Three point bending test

Flexural properties were assessed by performing three point bending test in a universal testing machine (Zwick / Roell). The testing was conducted according to the ISO 4049 specifications in such a way that the diameter for both supports and the loading piston was 2 mm and the span in between the supports was 20 mm and cross head speed was adjusted as 1 mm/min (**Fig. No: 31, 32**). Maximum load was recorded before the fracture. Flexural strength values were obtained directly from the computer's in-built software using the formula,

$S = 3FL/2bd^2$

Where,

'S' is the flexural strength (in MPa)

'F' is the maximum load applied to the specimen (Newton)

'L' is the span in between the supports (20 mm)

'b' and '**h'** are respectively the width and height of the specimen in mm.

Flexural modulus (Ef) is calculated from the following formula.

$Ef = SI^3 /4bh^3$

'I' is the span length (20.0 mm).

'b' is the width of test specimens

'h' is the thickness of test specimens

'S' is the stiffness (N/m) S=F/d

d is the deflection corresponding to load F at a point in the straight-line portion of the graph (Annexure - 2)

COLOUR PLATES

Fig. No: 1 - MATERIALS

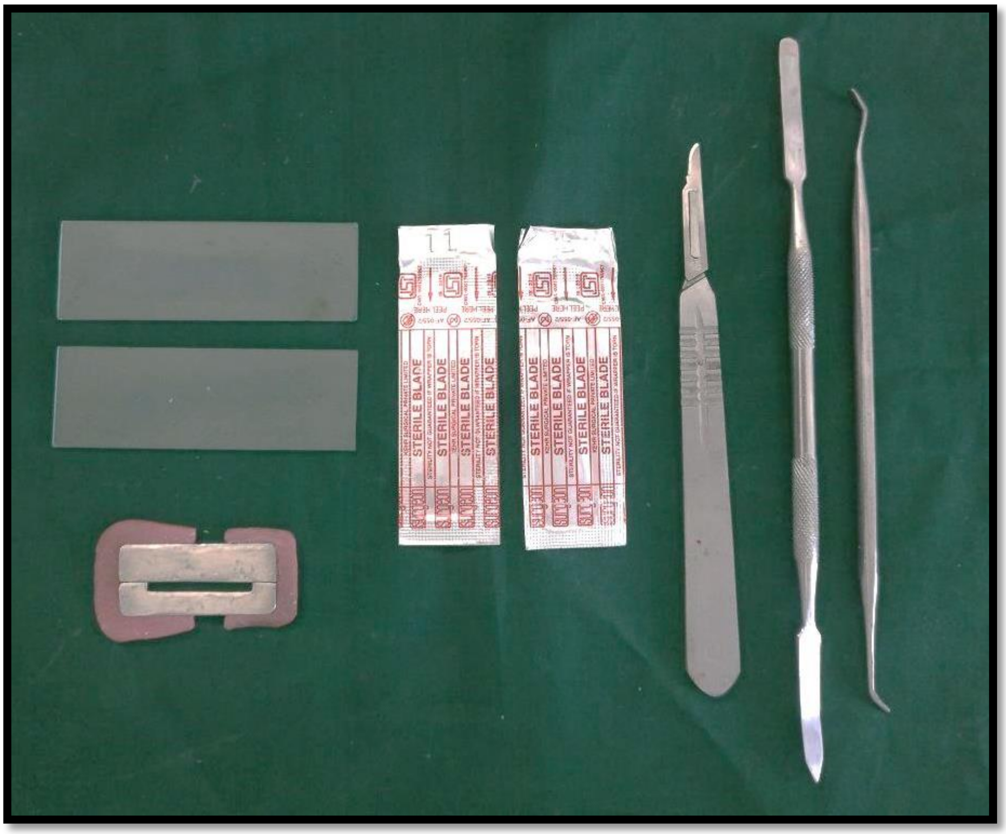


Fig. No: 2 - ARMAMENTARIUM

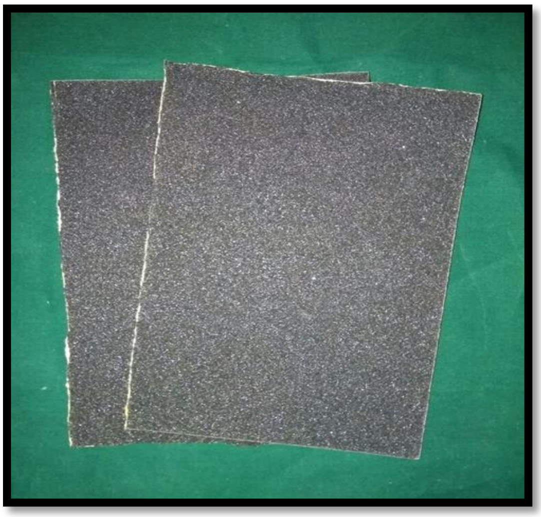


Fig. No: 3 – SAND PAPER

Fig. No: 4 – SEPARATING SHEETS

Fig. No: 5 – TISSUE PAPER

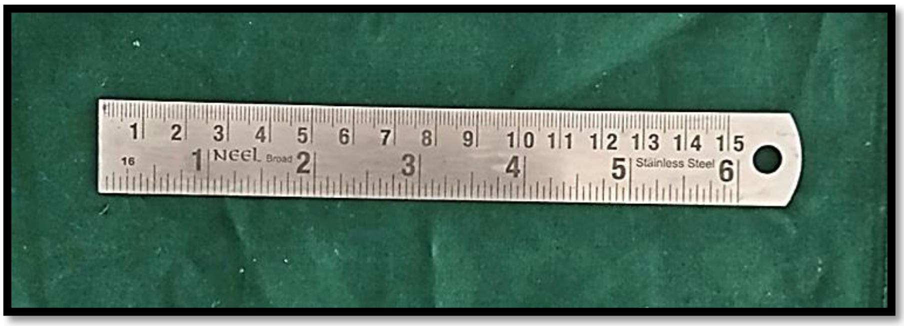


Fig. No: 6 - RULER

Fig. No: 7 – GLASS SLAB

Fig. No: 8 – INCUBATOR

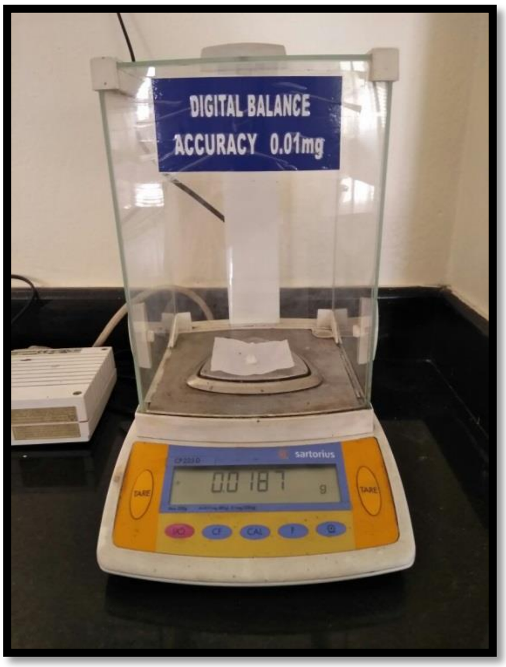


Fig. No: 9 – DIGITAL BALANCE

Fig. No: 10 – LIGHT CURING UNIT

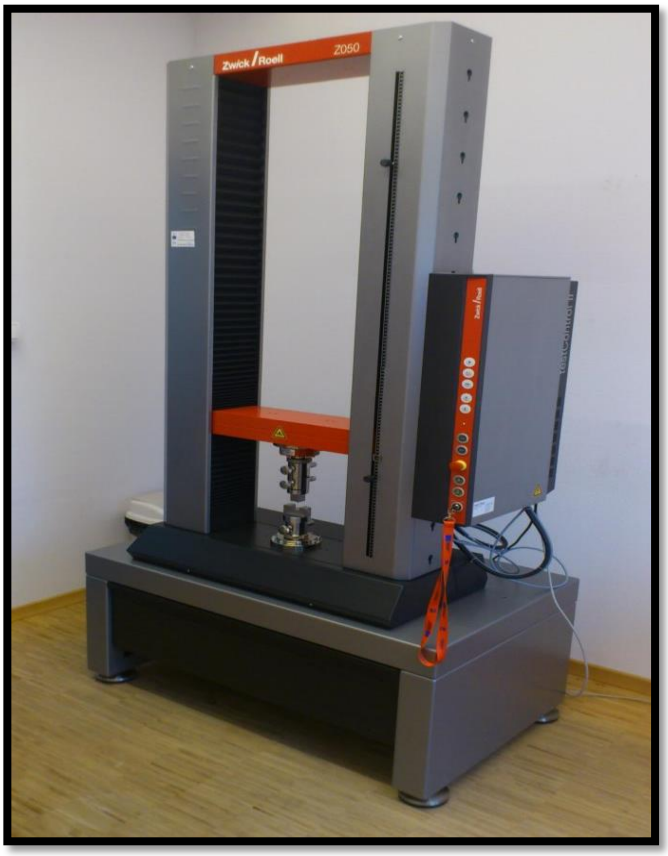


Fig. No: 11 - UNIVERSAL TESTING MACHINE - ZWICK ROELL

Fig. No: 12 - SCANNING ELECTRON MICROSCOPE – ZEISS

Fabrication of specimen for control group (GROUP A)

Fig. No: 13

Mould Assembly placed

On a Glass slide

Fig. No: 14

Packing of the Material into the Mould

Fig. No: 15

Material placement completed

Fig. No: 16

Placement of second glass slide over the packed material

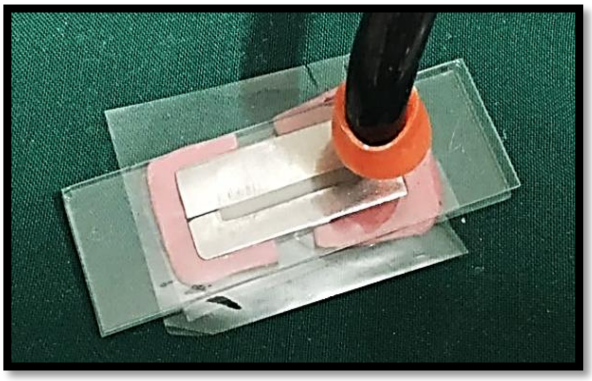


Fig. No: 17

Polymerisation of the specimen

Fig. No: 18 – SPECIMEN RETRIEVAL

Fabrication of specimens for fibre reinforced groups

Fig. No: 19 – Long S glass fibres

Fig. No: 20 – Chopped S glass Fibres (4 mm)

Fig. No 21: Wetting the glass fibres using silane agent

Fig. No: 22 - Wetted fibres were placed on the resin matrix

Fig. No: 23 – Fibres were mixed into the resin matrix

Fig. No: 24 - Group A specimens

Fig. No: 25 - Group B specimens

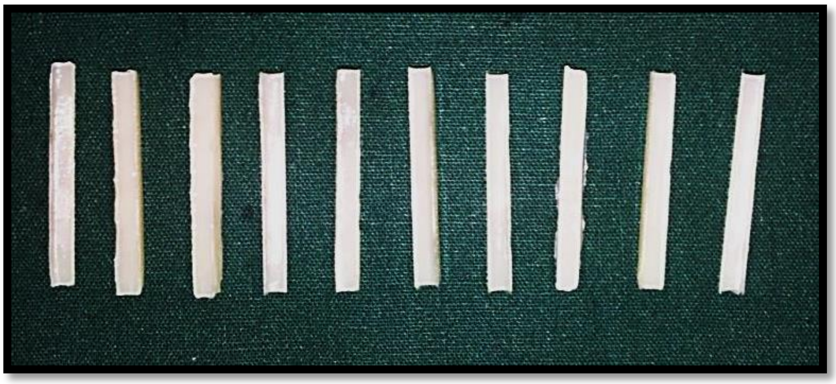


Fig. No: 26 - Group C specimens

Fig. No: 27 - Group D specimens

Fig. No: 28 - Group E specimens

Fig. No: 29 – Specimens in distilled water

Fig. No: 30 – Finished specimen

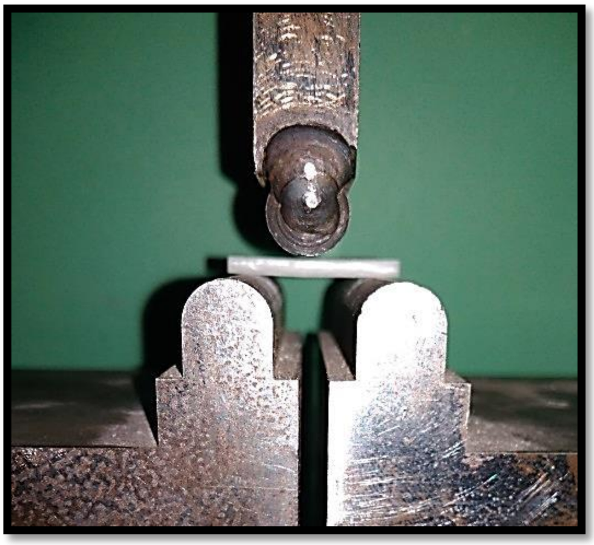


Fig. No: 31 – Specimen placed between the supports for 3-point bending test

Fig. No: 32- Fractured specimen

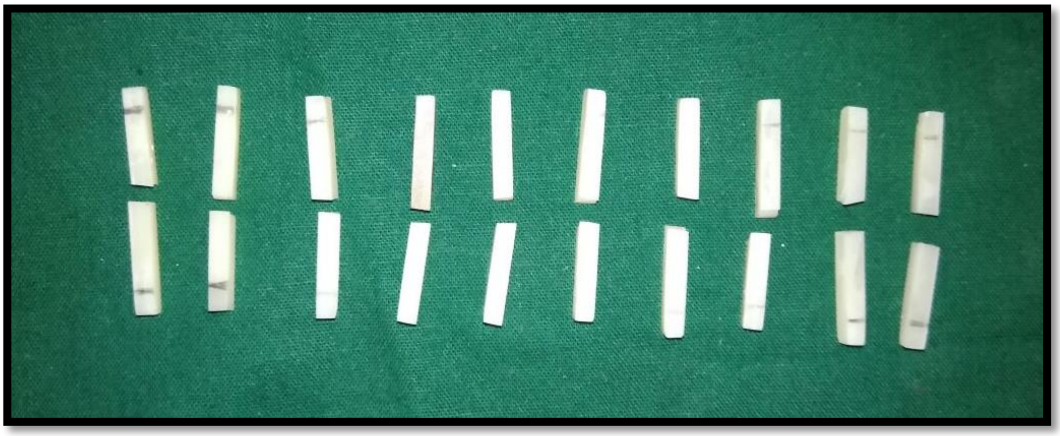


Fig. No: 33 – Fractured segments Group A specimens showing complete fracture

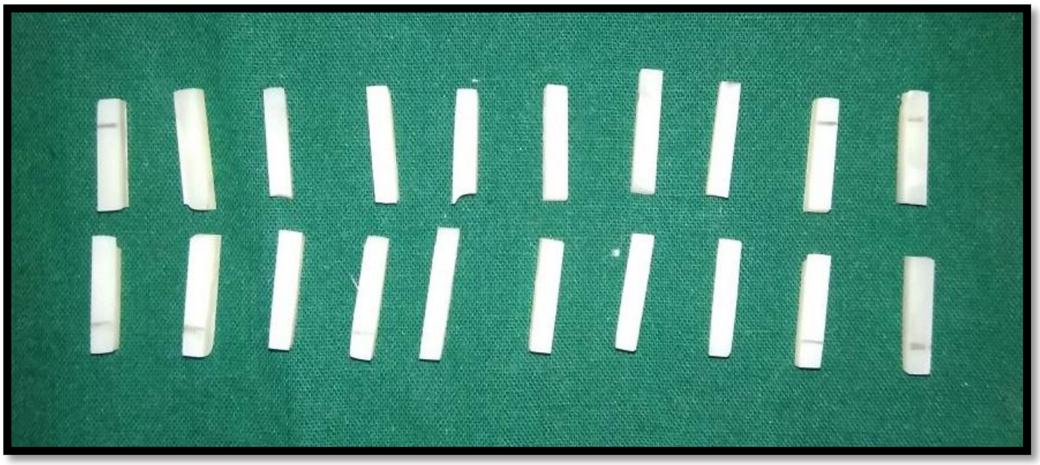


Fig. No: 34 – Fractured segments Group B specimens showing complete fracture

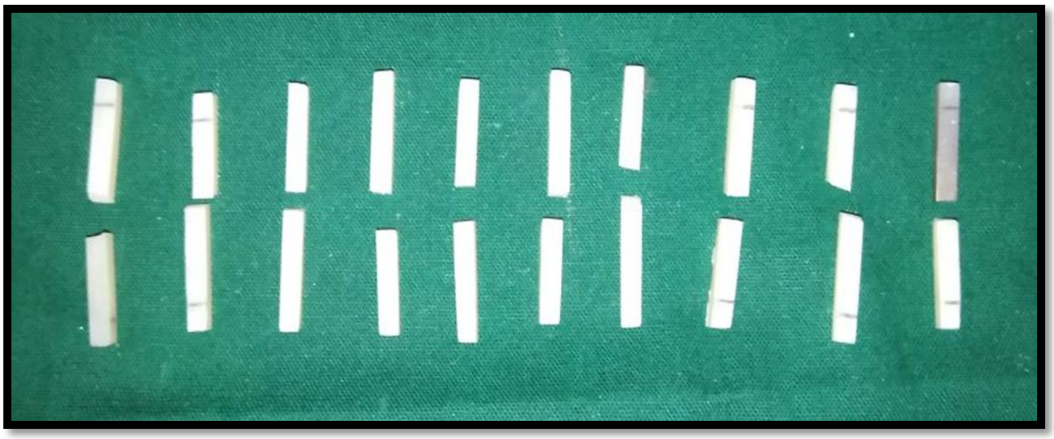


Fig. No: 35 – Fractured segments Group C specimens showing complete fracture

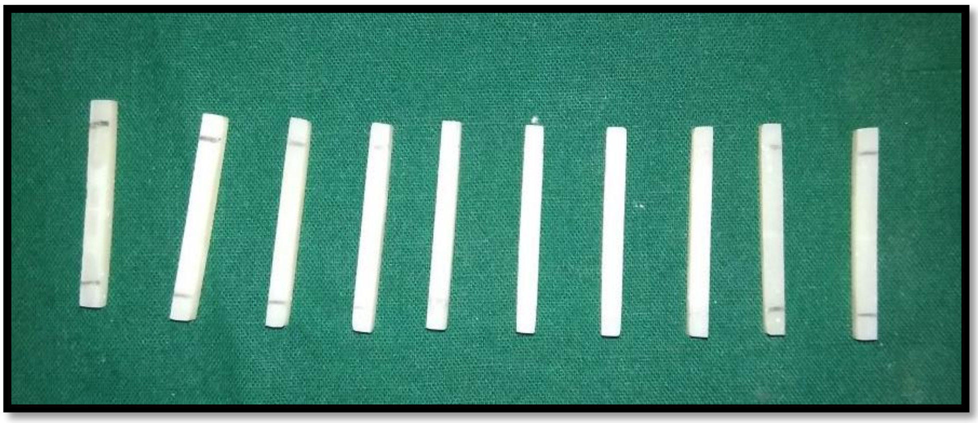


Fig. No: 36 – Fractured segments Group D specimens showing incomplete fracture

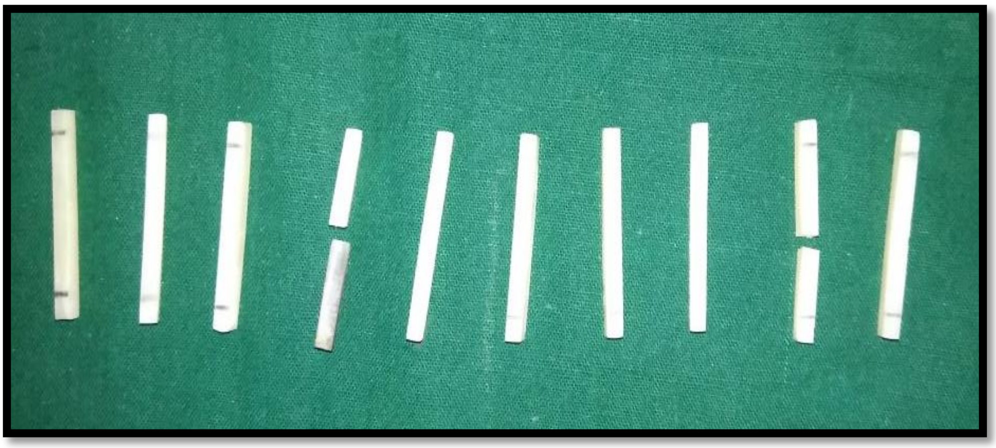


Fig. No: 37 – Fractured segments Group E specimens showing incomplete fracture

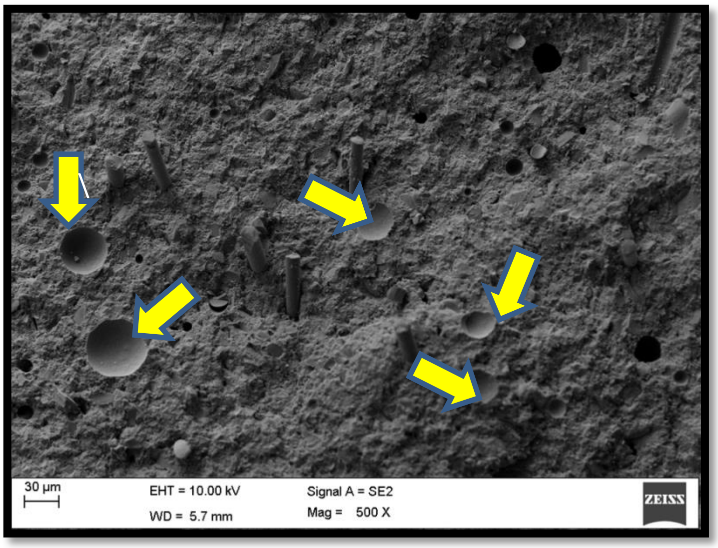


Fig. No: 38 - Fractured surface of the specimen (Group B) with the flexural strength of 249 MPa; Yellow arrows indicate the presence of voids.

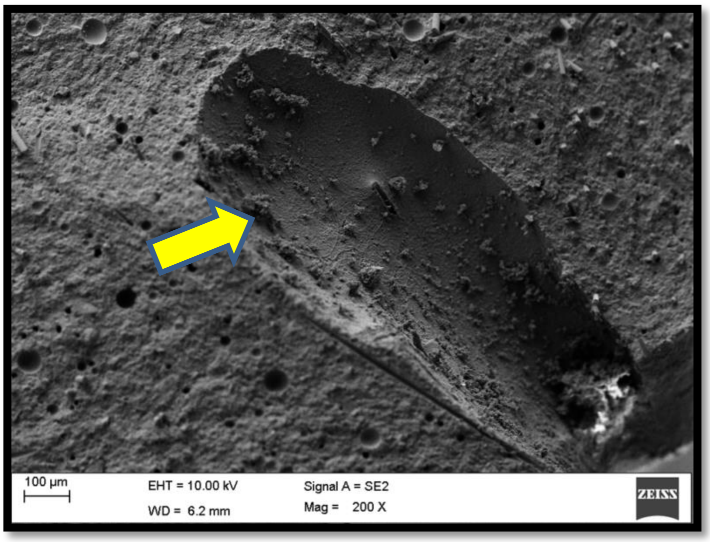


Fig. No: 39 - Fractured surface of the specimen (Group C) with the flexural strength of 88 MPa; Yellow arrow indicates the presence of a large void.

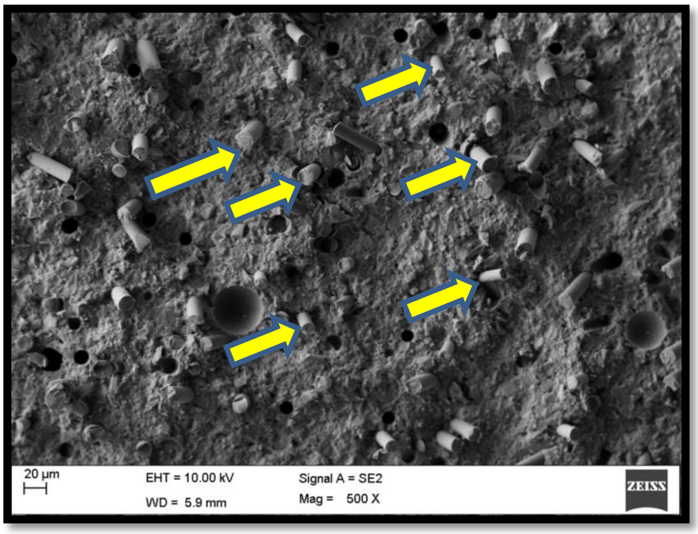


Fig. No: 40 - Fractured surface of the specimen (Group D) with the flexural strength of 245 MPa; Yellow arrows indicate the distribution of fibres more along the length of the specimen than in the transverse direction.

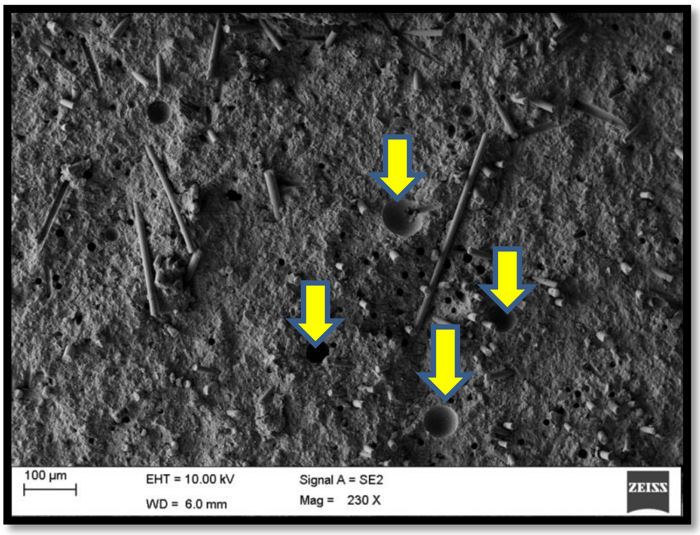


Fig. No: 41 - Fractured surface of the specimen (Group D) with the flexural strength of 245 MPa; Yellow arrows indicate the presence of voids.

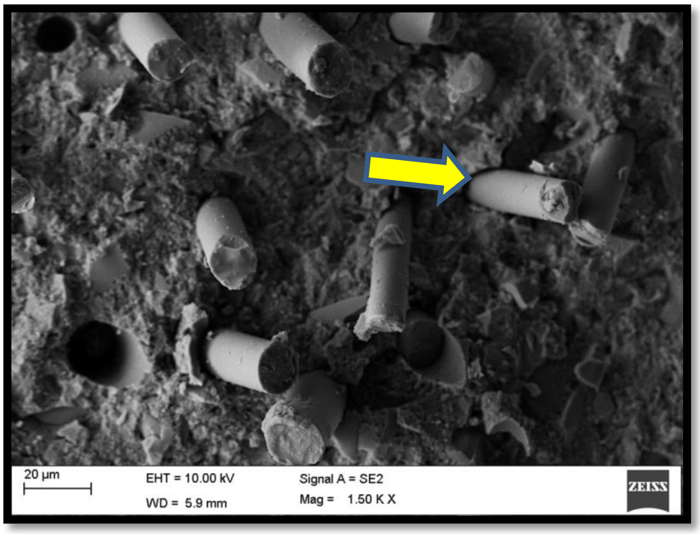


Fig. No: 42 - Fractured surface of the specimen (Group D) with the flexural strength of 245 MPa; Yellow arrow indicates the partial adherence of fibre to the resin matrix.

RESULTS

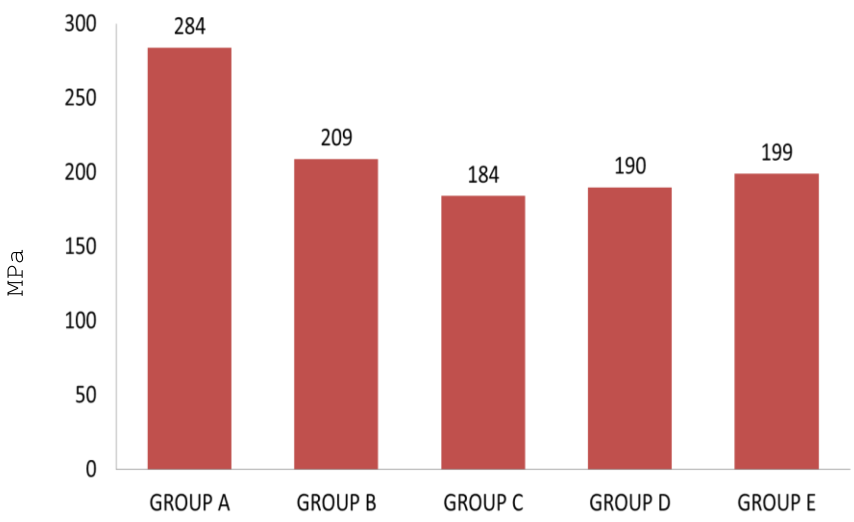
The values for each specimen are tabulated in the Annexure - 1.

As more than two groups were present to be compared in this study, One way- ANOVA test was used for statistical analysis. The confidence interval was set at 95%, so that p>0.05 could be considered as no significant difference present between the groups and p<0.05 could be considered with the presence of significant difference between the compared groups, with regard to mean.

TABLE 3: Mean and Standard deviation of Flexural strength (MPa) for the Control (A) and Reinforced groups (B, C, D and E)

Groups	Number of specimens	Mean	Std. Deviation	Std. Error
A	10	284.0000	33.15620	10.48491
B	10	209.8000	29.08914	9.19879
C	10	184.3500	37.50855	11.86125
D	10	190.8000	22.16002	7.00761
E	10	199.3000	33.44996	10.57781
Total	50	213.6500	47.41612	6.70565

Graph 1: comparison of mean values of Flexural strength (MPa) for the Control (A) and Reinforced groups (B, C, D and E)



The control group showed the highest mean flexural strength as 284 MPA followed by the reinforced groups B, E, D and C and their respective fibre volume content was 2.5, 10,7.5 and 5 Vol. %.

TABLE 4: Minimum and Maximum values of Flexural strength (MPa) for the Control (A) and Reinforced groups (B, C, D and E)

GROUPS	Minimum	Maximum
A	237.00	**345.00**
B	156.00	249.00
C	**88.50**	221.00
D	166.00	220.00
E	134	245.00

Table 4 shows minimum and maximum values of flexural strength of all the five groups compared; maximum flexural strength was shown by a specimen from control group A (nano hybrid composite resin) as 345 MPa and minimum flexural strength was shown by a specimen from reinforced group C (nano hybrid composite resin + 5 Vol.% of fibre) as 88.5 MPa .

TABLE 5: Results of Statistical analysis using One way-ANOVA for flexural strength

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	65504.800	4	16376.200	16.500	**.001**
Within Groups	44661.325	45	992.474		
Total	110166.125	49			

Since the p= .001 which was less 0.05, it could be concluded that there was a significant difference present between the groups. Further multiple comparisons were calculated by Post hoc test.

Table 6: Multiple inter group comparison using Post Hoc Test - TUKEY (HSD) for flexural strength

Pairwise comparisons Group	Group	Mean Difference	Std. Error	Sig.
A	B	74.20000*	14.08882	**.001**
	C	99.65000*	14.08882	**.001**
	D	93.20000*	14.08882	**.001**
	E	84.70000*	14.08882	**.001**
B	A	-74.20000*	14.08882	**.001**
	C	25.45000	14.08882	.383
	D	19.00000	14.08882	.663
	E	10.50000	14.08882	.945
C	A	-99.65000*	14.08882	**.001**
	B	-25.45000	14.08882	.383
	D	-6.45000	14.08882	.991
	E	-14.95000	14.08882	.825
D	A	-93.20000*	14.08882	**.001**
	B	-19.00000	14.08882	.663
	C	6.45000	14.08882	.991
	E	-8.50000	14.08882	.974
E	A	-84.70000*	14.08882	**.001**
	B	-10.50000	14.08882	.945
	C	14.95000	14.08882	.825
	D	8.50000	14.08882	.974

Tukey HSD statistical test showed that,

- When group A was compared to B, C, D and E, p=.001 (less than .05) which showed the presence of significant difference
- When group B was compared with C, p=.383 (more than .05) which showed that there was no significant difference present between the groups
- When group B was compared with D, p=.663 (more than .05) which showed that there was no significant difference present between the groups
- When group B was compared with E, p=.945 (more than .05) which showed that there

was no significant difference present between the groups

- When group C was compared with D, p=.991 (more than .05) which showed that there was no significant difference present between the groups
- When group C was compared with E, p=.825 (more than .05) which showed that there was no significant difference present between the groups
- When group D was compared with E, p=.974 (more than .05) which showed that there was no significant difference present between the groups

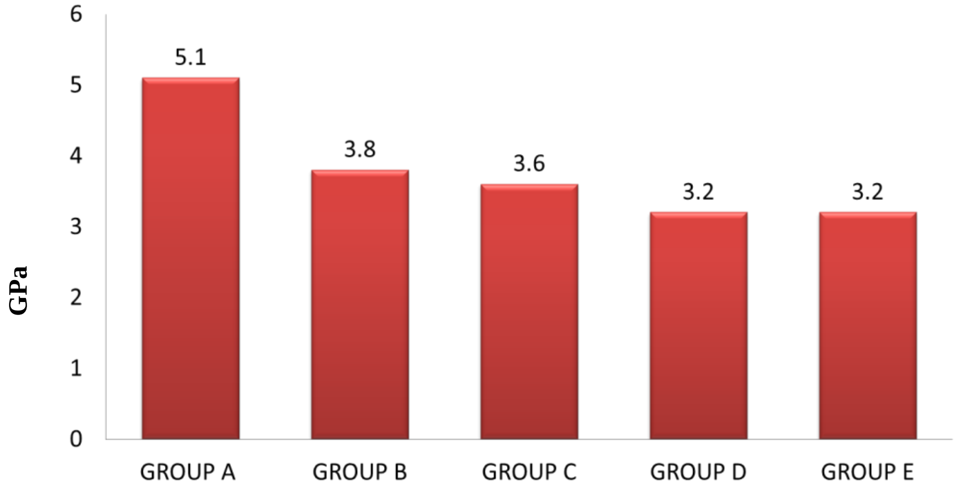
Through statistical analysis,

- By comparing the control group A and reinforced groups B, C, D and E, there was a significant difference present.
- By comparing between the reinforced groups B, C, D and E, there was no significant difference present.

TABLE 7: Mean and Standard deviation of Flexural Modulus (GPa) for the Control (A) and Reinforced groups (B, C, D and E)

	N	Mean	Std. Deviation	Std. Error
A	10	5.1800	1.19052	.37647
B	10	3.8000	.88819	.28087
C	10	3.6800	.84958	.26866
D	10	3.2600	1.84222	.58256
E	10	3.2600	1.20204	.38012
Total	50	3.8360	1.39134	.19676

Graph 2: Comparison of mean values of Flexural Modulus (GPa) for the Control (A) and Reinforced groups (B, C, D and E)



The control group showed the highest mean flexural modulus as 5.1 GPa followed by the reinforced groups B, C, D and E and their respective fibre volume content was 2.5, 5, 7.5 and 10 Vol. %.

TABLE 8: Minimum and Maximum values of Flexural Modulus (GPa) for the Control (A) and Reinforced groups (B, C, D and E)

GROUPS	Minimum	Maximum
A	4.00	7.20
B	2.60	5.80
C	2.40	4.80
D	**1.80**	**7.40**
E	**1.80**	5.60

Table 8 showed minimum and maximum values of flexural modulus of all the five groups compared; maximum flexural strength was shown by a specimen from reinforced group D (nano hybrid composite resin + 7.5 Vol. % of fibre) as 7.4 GPa and minimum flexural modulus was shown by specimens from reinforced group D and E (nano hybrid composite resin + 7.5 Vol. % of fibre and nano hybrid composite resin + 10 Vol. % of fibre respectively) as 1.8 GPa

TABLE 9: Statistical analysis - one way ANOVA for flexural modulus

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	24.955	4	6.239	4.016	**.007**
Within Groups	69.900	45	1.553		
Total	94.855	49			

Since the p value was less 0.05, it could be concluded that there was a significant difference present between the groups. Further multiple comparisons were calculated by Post hoc test.

Table 10: Multiple inter group comparison using Post Hoc Test - TUKEY (HSD) for flexural modulus

Pairwise comparisons		Mean Difference	Std. Error	Sig.
Group	Group			
A	B	1.38000	.55737	.114
	C	1.50000	.55737	.071
	D	1.92000*	.55737	**.010**
	E	1.92000*	.55737	**.010**
B	A	-1.38000	.55737	.114
	C	.12000	.55737	1.000
	D	.54000	.55737	.868
	E	.54000	.55737	.868
C	A	-1.50000	.55737	.071
	B	-.12000	.55737	1.000
	D	.42000	.55737	.942
	E	.42000	.55737	.942
D	A	-1.92000*	.55737	**.010**
	B	-.54000	.55737	.868
	C	-.42000	.55737	.942
	E	.00000	.55737	1.000
E	A	-1.92000*	.55737	**.010**
	B	-.54000	.55737	.868
	C	-.42000	.55737	.942
	D	.00000	.55737	1.000

Tukey HSD statistical test showed that,

- When group A was compared to D and E, p=.001 (less than .05) which showed the presence of significant difference
- When group A was compared with B, p=.114 (more than .05) which showed that there was no significant difference present between the groups
- When group A was compared with C, p=.071 (more than .05) which showed that there was no significant difference present between the groups

- When group B was compared with C, p=1.000 (more than .05) which showed that there was no significant difference present between the groups
- When group B was compared with D and E, p=.868 (more than .05) which showed that there was no significant difference present between the groups
- When group B was compared with E, p=.945 (more than .05) which showed that there was no significant difference present between the groups
- When group C was compared with D and E, p=.942 (more than .05) which showed that there was no significant difference present between the groups
- When group D was compared with E, p=1.000 (more than .05) which showed that there was no significant difference present between the groups

Through statistical analysis,

- By comparing the control group A and reinforced groups D and E, there was a significant difference present.
- By comparing the control group A and reinforced groups B and C, there was no significant difference present.
- By comparing between the reinforced groups B, C, D and E, there was no significant difference present.

SCANNING ELECTRON MICROSCOPIC ANALYSIS

The results of the study revealed that the flexural properties of specimens of the control group were superior in comparison to the specimens of glass fibre reinforced groups and there was no significant difference present between the reinforced groups in which the glass fibres were added in different volume proportions. So a microscopic analysis was carried out for the specimens of reinforced groups to assess the presence of voids, distribution and adhesion of fibres in the resin matrix. Three specimens were selected; two with highest flexural strength and one with lowest flexural strength. (**Fig. No: 38 - 42**)

DISCUSSION

Glass fibres are commonly used for reinforcing composite resins because of their superior esthetic properties, compatibility with the dental resins, ease of manipulation and surface treatment procedures. S glass fibres are high strength fibres particularly in tensile strength, which were found to have an influence in improving mechanical properties of composite resins. Fixed partial dentures which were made of fibre reinforced composite resin were found to have adequate survival rate when they were assessed for 3 to 4 years of follow up time [25, 35, 54]. Two systematic reviews had concluded that the available literature evidences were only adequate to support FRC restorations as medium term restorations and not as a long term or definitive restorations[7, 18]. In this study short S glass fibres were used for reinforcing nano hybrid composite resins, stored in distilled water at 37 ^{0}C for 24 hours and assessed for flexural strength by using 3-point bending test.

Nano hybrid composite resins

The volume of fillers, present in the composite resins plays a vital role in influencing the mechanical properties of the resins. Fillers are the inorganic substances which increase the strength by controlling the polymerisation shrinkage of the composite resins but compromise the esthetic outcome of the restoration. Nano hybrid composite resins shared both the advantages of increased strength and polishability because of their nano sized and micro sized filler particles. Nano hybrid composite resins were found to have high flexural strength and modulus than nano filled composites, after storing them in water or artificial saliva for 30 days[26, 28, 36].

Continuous Vs Discontinuous fibres

The use of long continuous fibres for reinforcing composite resins had increased the flexural strength especially when it was placed along the tensile side of a specimen or a restoration[12, 19]. But because of the anisotropic nature of the long continuous fibres, the polymerisation shrinkage could be minimized or prevented only along the direction of the fibres[22]. On the other hand, randomly oriented short discontinuous fibres and their isotropic nature, could control the polymerisation shrinkage uniformly along the entire length of a specimen or a restoration than long unidirectional continuous fibres and bidirectional woven fibres. But it was difficult to achieve random even distribution of short fibres inside the resin matrix of a specimen or a restoration. The dimensions of the specimen or contours of the restoration and length of the fibres could easily alter the orientation of the fibres from isotropic to anisotropic state.

Assessment of Fibre Length and Fibre Volume Proportions

S glass fibres used in this study were cut into 4mm for all the reinforced groups by calculating the critical length from the diameter of the fibres. The minimum length or the critical length needed for transferring the stress from resin matrix to the fibres should be at least 50 times more the diameter of the fibre. In this study, 4 different volume proportions were used for reinforcing nano hybrid composite resins; 2.5, 5, 7.5, 10 Vol. % to the entire volume of the specimen. The maximum volume loading was limited to 10 Vol. %, considering the difficulties in mixing and chances of creating flaws in the specimens[43].

Surface treatment for fibres

Fibres are available as pre impregnated and non-impregnated fibres. The non-impregnated fibres can be surface treated with silane coupling agents to improve the bonding between the fibres and resin matrix. Flexural strength of provisional restorative resins could be improved by reinforcing them with silane treated fibres than silane untreated fibres[37]. Glass fibres can be easily surface treated with silane agents. In this study, fibres were wetted by silane agents to get better adhesion with the resin matrix for the specimens fabricated for the reinforced groups (**Groups B, C, D** and **E**). After silane treatment, fibres were mixed with the resin matrix manually and polymerisation procedures were carried out.

Storage medium and Storage time

Sideridou et al.[26] did not observe any significant difference in the flexural strength of composite resins stored in different storage mediums such as distilled water and artificial saliva. Gundogdu et al.[34] used distilled water and mouthwash as storage mediums before conducting the flexural test. The testing was done after a day for half number of specimens and after 7 days for the rest half. They did not find any significant difference between the two storage mediums as well as between the two different storage times. For the present study, all the fabricated specimens were stored in distilled water for 24 hours.

Flexural testing

Flexural properties are very important for both definitive as well as for provisional restorations to bear high stress in the oral cavity. 3-point bending test is commonly employed for assessing the flexural properties of composite resins[20, 34, 37, 53]. The two supports in the 3-point bending test depict the retainers and the loading crosshead depicts the loading force across the pontic region in a fixed partial denture. However it is not an accurate testing method to imitate the clinical situation because loading forces in the oral cavity is multidirectional. But it is a nearly correlating test for an in vitro study to make clinical recommendations. For the present study flexural properties were assessed by preforming 3-point bending test in a universal testing machine and the values were obtained.

Flexural Strength and Flexural Modulus

The results of the study revealed that both flexural strength and modulus was significantly higher for the control group than for the reinforced groups. Regarding flexural strength there was a statistically significant difference present between the control group A and the reinforced groups B, C, D and E and for flexural modulus, there was a statistically significant difference present between the control group A and the reinforced groups D and E. The mean flexural strength value for the control group was 284 MPa and the mean flexural modulus was 5.18GPa. This could be correlated to already found results of nano hybrid composite resins studied by other authors[26, 38]. In fact, the mean flexural strength obtained in this study was greater than the flexural strength of dentin (261 MPa) and also greater than the results obtained after fibre reinforcement in some studies. Garoushi et al. had compared 5 commercially available fibre reinforced composite resin materials and the highest mean flexural strength obtained was 125 MPa[48]. Another study by the same author had concluded with the highest mean flexural strength of fibre reinforced composite resins as 124 MPa[31]. The volume of fillers of the nano hybrid composite resin used in the present study could be a reason for these increased values of flexural strength and modulus.

The significant difference between the control and reinforced groups was controversial to the results of some studies and correlated with few studies in which the fibre reinforcement decreased the flexural modulus of composite resins. Two in vitro studies concluded with the reduced values of flexural modulus for the reinforced groups than the unreinforced control groups[44, 50]. One of the studies used non-impregnated short S glass fibres and the other used silane treated fibres. Using long unidirectional impregnated E glass fibres for reinforcing composite resins had resulted in increased flexural strength[34].

Scanning electron microscopic analysis of the specimens of the reinforced groups revealed that the orientation of the fibres were predominantly unidirectional along the length of the specimens. This orientation had altered the isotropic nature of short fibres to anisotropic. The critical length of the fibre used in this study was 4mm which was actually greater than height (2 mm) and width (2 mm) of the mould. Mould dimension and manual mixing would have resulted in unidirectional orientation of the fibres.

Secondly, presence of macro and micro voids were seen throughout the fractured surface of the specimens. There was a macro void present in the specimen with the lowest flexural strength of 88.5 MPa. While fabricating the specimens for the reinforced groups, after mixing the fibres with the resin matrix, the material was packed into the mould as a whole and cured without incremental addition and curing. Microscopic analysis also revealed that adhesion between the fibres and resin matrix was partial.

Pattern of fracture

Two types of fractures were observed in this study; complete and incomplete or partial fracture. For the control group A and reinforced groups B and C (fibre Vol. % was 2.5 and 5 respectively) complete fracture was observed between the fractured ends. This could be considered as a catastrophic failure for a clinical situation. For the fibre reinforced groups D and E (fibre Vol. % was 7.5 and 10 respectively), incomplete and partial fracture was seen between the fractured ends of the tested specimens. Fibres were holding the two fractured ends of the specimen preventing them from complete fracture. This finding was in correlation to the earlier studies of fibre reinforced composite resins[23, 34].

The presence of voids and the partial adherence of fibres with the resin matrix of the specimens of the reinforced groups were found as unfavourable findings for the present study. Incremental addition and curing of resin material into mould as well as using vacuum/pressure mixer for mixing fibres with the composite resin could be used to prevent the above flaws. The orientation of the fibres and their isotropic nature could be maintained by using appropriate fibre length (more than or equal to the critical length) which should not get influenced or altered by the dimension of the mould to be used.

Further in vitro studies, which can eliminate the unfavourable findings of the present study and in vivo studies are recommended to make decisions regarding clinical application of these materials.

SUMMARY & CONCLUSION

The present in vitro study was carried out to evaluate the flexural properties of nano hybrid composite resins reinforced with short S glass fibres. The specimens were fabricated in 5 groups; 1 control group (A) and 4 reinforced groups (B, C, D and E). The fibres were cut into 4 mm length and added in 4 different volume proportions as 2.5, 5, 7.5 and 10 Vol. % to B, C, D and E groups respectively. All the fabricated specimens were stored in distilled water at 37^{0} C for 24 hours and assessed for flexural strength and modulus by performing 3-point bending test. The results of the study showed statistically significant difference between the control and reinforced groups in which the control group specimens showed superior strength and modulus than the reinforced groups.

At the end of the study, the first null hypothesis was rejected and second null hypothesis was accepted.

Within the limitations of the study, it was concluded that:

1. The control group – Polofil NHT, Nano hybrid composite resin showed higher flexural strength and modulus which was statistically significant than the short S glass fibre reinforced groups of different volume proportions. Addition of S glass fibres decreased the flexural strength and modulus of the nano hybrid composite resin rather than increasing the flexural strength and modulus.
2. There was no significant difference present among the fibre reinforced groups of different volume proportions, both in terms of flexural strength and modulus. Considering the pattern of fracture, reinforced groups E and D with their fibre volume of 7.5 and 10 respectively, was found to show partial or incomplete separation of the fractured segments.

3. Polofil NHT showed superior flexural properties without any fibre reinforcement. With the results obtained, from a clinical point of view Polofil NHT could be recommended to be used as a long tern provisional restorative material for fixed partial dentures.

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ANNEXURE – 1

THE VALUES FOR EACH SPECIMEN

Group A- Control (Nano hybrid composite resin)

S.No	Load (Newton)	Deflection (%)	Flexural Strength (MPa)	Flexural Modulus (GPa)
1	63.2	0.89	237	6.7
2	65.06	1.48	244	4.1
3	74.13	1.58	278	4.4
4	92	1.59	345	5.4
5	71.73	1.680.	269	4
6	75.46	1.73	283	4.1
7	73.33	1.54	275	4.5
8	81.6	1.53	306	5
9	74.66	1.10	280	6.4
10	86.13	1.12	323	7.2

Group B- Nano hybrid composite resin+2.5 Vol. % of fibres

S.No	Load (Newton)	Deflection (%)	Flexural Strength (MPa)	Flexural Modulus (GPa)
11	52.8	1.64	198	3
12	41.6	1.51	156	2.6
13	56.53	1.45	212	3.6
14	51.73	1.34	194	3.6
15	48.53	1.33	182	3.4
16	66.4	1.55	249	4
17	62.93	1.66	236	3.5
18	58.4	1.39	219	3.9
19	55.2	1.12	207	4.6
20	65.33	1.05	245	5.8

Group C- Nano hybrid composite resin +5 Vol. % of fibres

S.No	Load (Newton)	Deflection (%)	Flexural Strength (MPa)	Flexural Modulus (GPa)
21	44.53	1.76	167	2.4
22	52	1.46	195	3.3
23	53.06	1.14	199	4.4
24	51.4	1.84	193	2.6
25	56.26	1.54	211	3.4
26	49.6	1.03	186	4.5
27	58.93	1.68	221	3.3
28	55.73	1.51	209	3.5
29	46.4	0.91	174	4.8
30	23.6	0.48	88.5	4.6

Group D- Nano hybrid composite resin +7.5 Vol. % of fibres

S.No	Load (Newton)	Deflection (%)	Flexural Strength (MPa)	Flexural Modulus (GPa)
31	44.8	2.29	168	1.8
32	54.4	1.77	204	2.9
33	44.26	2.02	166	2
34	57.6	1.91	216	2.8
35	52.8	1.71	198	2.9
36	44.53	1.60	167	2.6
37	49.33	1.94	185	2.4
38	45.33	2.10	170	2
39	58.66	0.94	220	5.8
40	57.06	0.72	214	7.4

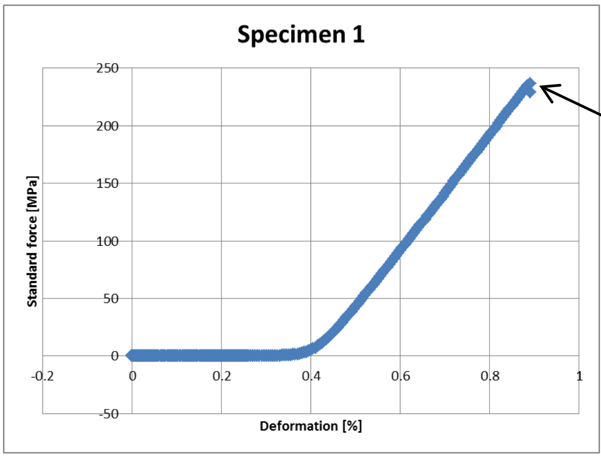
Group E- Nano hybrid composite resin +10 Vol. % of fibres

S.No	Load (Newton)	Deflection (%)	Flexural Strength (MPa)	Flexural Modulus (GPa)
41	59.46	1.76	223	3.1
42	35.73	1.81	134	1.8
43	55.2	1.91	207	2.7
44	57.06	1.96	214	2.7
45	45.6	1.86	171	2.3
46	49.86	1.79	187	2.6
47	65.33	1.60	245	3.8
48	60	1.91	225	3
49	58.13	0.98	218	5.6
50	45.06	0.85	169	5

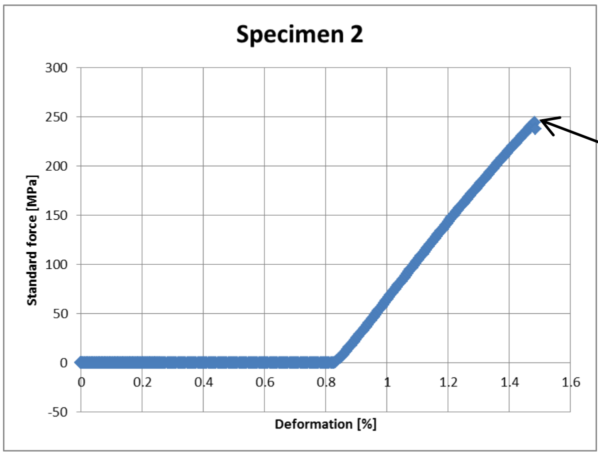
ANNEXURE – 2

GRAPHICAL READINGS OF DEFORMATION

Examples:



Point of deflection is at 0.89



Point of deflection is at 1.48